Impact of Supplemental Phosphorus Source on Phosphorus Utilization in Lactating Dairy Cattle

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Summary

Supplemental phosphorus (**P**) in various forms and sources (pellet, meal, liquid, and corn dried distillers grains with solubles; **DDGS**) were compared in 12 multiparous Holstein cows producing 94.8 lb of milk (115 ± 55 days in milk) in a 4 × 4 Latin square with 21-day periods. The pellet and meal diets contained monocalcium phosphate with a wheat middlings carrier, and the liquid diet contained ammonium polyphosphate in a cane molasses base. The DDGS supplied an organic P source. Cows were blocked by parity, days in milk, and milk production and randomly assigned to treatments. Phosphorus intakes were similar among all 4 diets (116, 116, 119 and 118 g/day for pellet, meal, liquid and DDGS diets, respectively). Cows consuming the liquid diet experienced greater ($P < 0.001$) sugar intakes. Milk yield differed ($P = 0.05$) among diets, with the DDGS diet yielding the most milk (76.3, 78.1, 75.2 and 80.5 lb/day for pellet, meal, liquid, and DDGS diets, respectively). There were no differences in milk fat and milk protein percentages or in daily lactose production. Excretion of P in feces tended ($P = 0.07$) to differ among treatments (67.4, 66.3, 57.5, and 60.0 g/day for pellet, meal, liquid and DDGS diets, respectively), resulting in a trend ($P = 0.10$) for greater P retention from diets, resulting in less P excretion. Secretion of P in milk did not differ among treatments. These data show that supplemental P source does not affect dry matter intake or P intake. Phosphorus source resulted in slight differences in P utilization, but it was not related to sorting of the diet. The DDGS diet showed responses similar to those of inorganic P mineral supplements and had favorable production yields, indicating that DDGS is an adequate substitute for mineral sources of P.

Introduction

Developing feeding strategies that reduce phosphorus (**P**) excretion is crucial to alleviating the potential environmental hazards of P entering surface water and the resulting algal growth and eutrophication. The 2001 Nutrient Requirements for Dairy Cattle recommended P feeding level is 0.32 to 0.42%, depending on the physiological status of the animal, and research has shown that levels beyond this range are unnecessary. Overfeeding P often is practiced to ensure adequate P absorption to meet the cow's needs for milk production and reproduction; however, reproductive efficiency may decrease only when dietary levels fall below 0.2%. It is well known that feeding excess dietary P results in increased P in the manure and increased feed expense. The objective of this experiment was to analyze the effects of various sources of supplemental P presented in 3 forms on milk production and composition, P partitioning in the cow, and diet sorting in lactating dairy cows.

Experimental Procedures

Twelve multiparous lactating dairy cows (115 ± 55 days in milk; 98 ± 14 lb milk) were fed 1 of 4 diets with similar P levels but different forms and sources of P in a 4 × 4 Latin square design with 3 replications. Treatment periods were 21 days in duration; the first 14 days served as an adaptation period, and the last 7 days were used to collect data. Cows were assigned randomly to treatments after treatments were balanced by days in milk, milk yield, and parity. Inorganic P forms and sources were a wheat middlings-based meal diet and a pellet diet containing monocalcium phosphate and a molasses-based liquid diet containing ammonium polyphosphate.

The fourth diet used corn dried distillers grains with solubles (**DDGS**) as an organic source of supplemental P for comparison with inorganic sources and was presented in meal form.

Cows were milked twice daily at 0500 and 1600 hours. Milk weights were recorded at each milking, and duplicate milk samples were collected for 6 consecutive milkings beginning on day 1 of the collection week each period. One sample was collected in a vial with preservative; the second was collected in a vial without preservative and frozen for later analysis. Fecal grab samples were collected every 8 hours for 4 days beginning on day 1 of the collection week, and sampling time advanced 2 hours each day to account for diurnal variation.

Data were analyzed using the MIXED procedure of SAS version 9.1 (SAS Institute Inc., Cary, NC). The model statement included the effects of diet, replication, and the interaction between diet and replication as fixed effects. Random effects were cow and period. Treatment means were determined by using the LSMEANS option, and orthogonal contrasts were performed. Significance was determined at $P \leq 0.05$.

Results and Discussion

Ingredients included in the diets are listed in Table 1. Diets were formulated to contain similar amounts of all nutrients, and adjustments were made for the inclusion of DDGS in the DDGS diet. Corn grain and Soy Best (Grain States Soya, West Point, NE) were reduced to account for the protein and energy supplied by the DDGS. Because the pellet, meal, and liquid diets differed only in P form, a base total mixed ration was mixed daily, and sufficient amounts were obtained to feed the cows on the selected treatment. Supplemental P was added to the base ration and mixed in a stand-alone drum tumble mixer (Data Ranger; American Calan, Northwood, NH). The DDGS diet was mixed separately, and the DDGS was added as a component of a grain mixture.

Dietary nutrient composition analysis (Table 2) showed dietary P concentrations of 0.46, 0.47, 0.49, and 0.47% for the pellet, meal, liquid, and DDGS diets, respectively. Fat and starch content of the DDGS diet were more than 17% greater and 11% less, respectively, than those of the other diets. There seemed to be small differences in mineral composition, but all other nutrients were similar across all diets.

Dry matter intake was similar across treatments, which explains the similarities in nutrient intake across treatments (Table 3). Fat intake was greater ($P < 0.001$) for the DDGS diet than for the other treatments. The solubles portion of DDGS is added back to the distillers grains after starch is extracted from the corn endosperm for ethanol production. The solubles contain oil from the corn germ and increase the fat content of the distillers grains. Decreasing corn grain in the DDGS diet decreased ($P = 0.004$) starch intake compared with the pellet and meal diets and tended ($P = 0.08$) to reduce starch intake compared with the liquid diet. The additional molasses supplied by the P supplement in the liquid diet increased ($P < 0.001$) sugar intake above that of all other treatments. Values for net energy for lactation intake were not different among treatments. Similarly, intakes of nonstructural carbohydrates were not different despite differences in starch and sugar intakes. Ash intake was not different across treatments, but instances of differing mineral intakes exist because of differences in mineral content of the diets. All minerals, however, were within sufficient ranges that would not affect experimental treatments.

Milk production was greater for the DDGS diet than for the pellet and meal diets (Table 3). Contrasts were performed to compare the inorganic P source supplied in the pellet and meal diets with the organic P source in the DDGS diet and the inorganic P source in the liquid diet as well as to compare the inorganic P source in the liquid diet with the organic P source. Phosphorus source affected milk production ($P = 0.05$); the DDGS diet supported 3.3 lb/day more milk production than the inorganic P sources ($P = 0.05$) and 5.3 lb/day more milk production than the liquid diet ($P = 0.01$). The increase in milk production is not necessarily due to P intake. Milk fat and milk protein percentages were unaffected by treatment, In contrast, the liquid diet produced less fat than the inorganic ($P = 0.05$) and organic ($P = 0.01$) sources. Small decreases in milk fat percentage can occur with molasses supplementation. Sugar from molasses is readily soluble by ruminal microbes in the rumen, which increases propionate production. This leads to a decrease in the amount of acetate available for milk fat synthesis in the mammary gland. Daily milk protein production favored the DDGS diet, which had greater protein production than the inorganic ($P = 0.03$) and liquid ($P = 0.01$) diets, whereas no difference existed between inorganic and liquid P sources. Increases in daily protein and fat production followed an increase in milk yield. Fat-corrected milk was lower ($P = 0.009$) for the liquid diet compared with the organic P supplement. Fat-corrected milk for the liquid diet was also lower ($P = 0.05$) than for the inorganic P source.

As formulated, and along with similarities in dry matter intake, P intakes were similar across diets, but P utilization was different in some instances (Table 4). Dietary levels of P in this experiment would be sufficient for lactating cows producing more than 88 lb/day (based on the 2001 National Research Council-recommended value for dairy). Mean milk production over the length of the trial was less than 88 lb/day, resulting in cows being over supplemented with P near the end of the trial, when milk production was decreasing. Fecal P excretion tended ($P = 0.07$)to be greater for the inorganic diets than for the organic diet and was greater ($P = 0.02$) for the inorganic diet than for the liquid diet, but no difference existed between the liquid and organic dietary P supplements. Calculating P balance as P intake minus fecal and milk P resulted in a tendency ($P = 0.10$) for the organic supplement to retain approximately 9 g/day more P than the inorganic supplement. The liquid diet also retained ($P = 0.02$) more P than (13.5 g/day) than diets supplemented with inorganic P.

Table 1. Ingredient composition of total mixed rations

	Treatments[1]			
Ingredient, % of diet dry matter	Pellet	Meal	Liquid	DDGS
Corn silage	33.28	33.28	33.56	32.38
Alfalfa hay	25.66	25.66	25.97	24.98
Whole cottonseed	5.14	5.14	5.14	5.00
Corn grain, ground	18.40	18.40	18.68	14.65
Soy Best[2]	10.15	10.15	10.15	2.88
Sodium bicarbonate	0.76	0.76	0.76	0.74
Magnesium oxide	0.13	0.13	0.13	0.13
MFP[3]	0.09	0.09	0.09	0.09
Zinpro 4-Plex[4]	0.05	0.05	0.05	0.05
Sodium selenite, 0.06%	0.04	0.04	0.04	0.04
Vitamin A premix, 30,000/g	0.02	0.02	0.02	0.02
Vitamin E premix, 20,000/g	0.19	0.19	0.19	0.18
XP Yeast[5]	0.21	0.21	0.21	0.21
Rumensin[6]	0.01	0.01	0.01	0.01
Cane molasses	0.90	0.90	2.88	0.68
DDGS	—	—	—	16.43
Wheat middlings	3.55	3.55	—	—
Salt	0.28	0.28	0.32	0.28
Calcium carbonate	0.76	0.76	1.00	1.10
Monocalcium phosphate	0.38	0.38	—	0.15
Ammonium polyphosphate	—	—	0.80	—

[1] Supplemental phosphorus sources: wheat middling base containing monocalcium phosphate in pelleted (Pellet) and meal (Meal) forms; cane molasses base containing ammonium polyphosphate (Liquid); corn dried distillers grains with solubles (DDGS).
[2] Grain States Soya, West Point, NE.
[3] Dry source of 84% active methionine. Novus International, Inc., St. Charles, MO.
[4] Nutrient premix containing 2.58% zinc, 1.43% manganese, 0.90% copper, 0.18 % cobalt, 8.21% methionine, 3.80% lysine, 11.5% protein, 1.5% fat, 22.0% fiber, and 26.5% ash; Zinpro Corp., Eden Prairie, MN.
[5] Diamond V Mills, Inc., Cedar Rapids, IA.
[6] Elanco, Greenfield, IN.

Table 2. Nutrient composition of total mixed rations containing various phosphorus supplements

	Treatments[1]			
Nutrient (dry matter basis)	Pellet	Meal	Liquid	DDGS
Crude protein, %	16.6	16.6	16.8	17.2
Acid detergent fiber, %	18.6	18.5	18.5	19.0
Neutral detergent fiber, %	29.9	29.9	29.2	31.3
Fat, %	4.7	4.6	4.6	5.6
Sugar, %	5.2	5.2	6.4	4.7
Nonstructural carbohydrates, %	43.4	43.3	42.4	41.2
NE_L[2], Mcal/kg	1.70	1.69	1.66	1.73
Ash, %	7.7	8.0	8.0	7.8
Calcium, %	1.0	1.1	1.1	1.2
Phosphorus, %	0.46	0.47	0.49	0.47
Magnesum, %	0.29	0.29	0.29	0.28
Potassium, %	1.6	1.6	1.7	1.5

[1] Supplemental phosphorus sources: wheat middling base containing monocalcium phosphate in pelleted (Pellet) and meal (Meal) forms; cane molasses base containing ammonium polyphosphate (Liquid); corn dried distillers grains with solubles (DDGS).

[2] Net energy of lactation.

Table 3. Effect of supplemental phosphorus source and form in total mixed rations on lactating dairy cattle performance

	Treatment[1]						Contrast		
Item	Pellet	Meal	Liquid	DDGS	SEM	*P*	I vs. O[2]	I vs. L[3]	L vs. O[4]
Dry matter intake, lb/day	54.5	54.0	53.4	54.0	1.8	0.97	0.90	0.67	0.78
Milk, lb/day	76.3[a]	78.1[ab]	75.2[a]	80.5[b]	2.80	0.05	0.05	0.25	0.01
Milk fat, %	3.68	3.83	3.58	3.68	0.16	0.26	0.47	0.11	0.43
Milk protein, %	3.05	3.09	3.08	3.12	0.06	0.33	0.13	0.67	0.33
Milk fat, lb/day	2.80[ab]	2.98[b]	2.69[a]	2.95[b]	0.18	0.05	0.50	0.05	0.03
Milk protein, lb/day	2.31[a]	2.40[ab]	2.32[a]	2.49[b]	0.09	0.04	0.03	0.34	0.01
SNF[5], lb/day	6.6[a]	6.8[ab]	6.6[a]	7.1[b]	0.29	0.05	0.06	0.24	0.01
Log somatic cell count	2.09	1.90	2.03	2.21	0.18	0.29	0.14	0.82	0.27
Milk urea N, mg/dL	14.9	14.7	15.4	14.3	0.73	0.12	0.19	0.14	0.02
FCM[6], kg/day	32.8[ab]	34.4[b]	32.0[a]	34.6[b]	1.55	0.03	0.21	0.05	0.009

[abc] Means within a row with differing superscripts differ ($P < 0.05$).
[1] Supplemental phosphorus (P) sources: wheat middling base containing monocalcium phosphate in pelleted (Pellet) and meal (Meal) forms; cane molasses base containing ammonium polyphosphate (Liquid); corn dried distillers grains with solubles (DDGS).
[2] Inorganic P source vs. organic P source = pellet and meal vs. DDGS.
[3] Inorganic P source vs. liquid P source = pellet and meal vs. liquid.
[4] Liquid P source vs. organic P source = liquid vs. DDGS.
[5] Solids nonfat.
[6] Fat-corrected milk = (0.4 × lb of milk) + (15 × lb of milk fat).

Table 4. Effect of supplemental phosphorus source and form on phosphorus partitioning in lactating dairy cattle

	Treatment[1]						Contrast		
Item	Pellet	Meal	Liquid	DDGS	SEM	*P*	I vs. O[2]	I vs. L[3]	L vs. O[4]
P intake, g/day	116	116	119	118	5.05	0.93	0.75	0.53	0.79
Fecal P excretion, g/day	67.4	66.3	57.5	60.0	3.54	0.07	0.07	0.02	0.54
Milk P concentration, g/day	36.6	39.0	36.4	37.2	1.84	0.51	0.72	0.39	0.66
P balance, g/day	11.7	11.1	25.1	20.3	5.23	0.08	0.10	0.02	0.43

[1] Supplemental phosphorus (P) sources: wheat middling base containing monocalcium phosphate in pelleted (Pellet) and meal (Meal) forms; cane molasses base containing ammonium polyphosphate (Liquid); corn dried distillers grains with solubles (DDGS).
[2] Inorganic P source vs. organic P source = pellet and meal vs. DDGS.
[3] Inorganic P source vs. liquid P source = pellet and meal vs. liquid.
[4] Liquid P source vs. organic P source = liquid vs. DDGS.